PEAK OF FLIGHT NEWSLETTER

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Making Fiberglass Body Tubes for FAI Rockets - Part 3

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Apogee Components, Inc.
Your Source For Rocket Supplies That Will Take You To The "Peak-of-Flight"
3355 Fillmore Ridge Heights Colorado Springs, Colorado 80907-9024 USA
www.ApogeeRockets.com e-mail: orders@apogeerockets.com Phone: 719-535-9335 Fax: 719-534-9050

Making Fiberglass Body Tubes for FAI Rockets - Part 3

By Tim Van Milligan

In part two of this series found at: (http://www.ApogeeRockets.com/education/downloads/Newsletter431.pdf), the tubes I was making were beginning to pick up the qualities that I wanted.

So the initial process for making competition (FAI-style) fiberglass tubes was written down, and I want to stress how it is a "process," much like cooking or baking. If you do steps in the wrong order, or do them incorrectly, the tubes can easily be ruined. I found this out a lot during my experimenting. I ruined dozens and dozens of tubes.

If you recall, the ultimate goal that I was trying to achieve was to make a colorful, lightweight tube that had a glass-smooth surface. Most importantly, it had to be fairly easy to make so that many tubes of consistent quality could be produced. I needed a lot of tubes for the various events in the actual competition and for use in practicing.

"Why Don't You Shoot Some Air Into It Tim?"

My biggest problem was ruining a lot of tubes while trying to remove the ultra thin wall fiberglass tube from the aluminum mandrel. The tubes are so fragile that they are easily torn by rough handling.

The suggestion that I received a lot, after explaining the trials I was going through while trying to remove the shell from the mandrel, was "why don't you try to shoot some compressed air under the edge."

I tried that a hundred times… I never had any luck with removing the mandrel using compressed air. Only in hindsight did I figure out why this might be the case.

Shooting air under the edge would probably work just fine if two things weren't working against me. The first is having the tube made from epoxy. You have to put this into perspective; epoxy is an adhesive. It is engineered to "stick." It wants to stick to the mandrel, because that is its purpose, and true to its nature, sticking it does.

The only thing that prevents it from sticking to the mandrel is the mold release applied to the mandrel.

The thing that epoxy has going for it,is that it is also in the "plastics" material category. The nice thing about plastic is that it is somewhat flexible. That is why if you have two plastic buckets stuck together, you can shoot air or water in between them, and they will separate. The reason this works is because the plastic is flexible and deforms slightly as the air gets under the edge. In fact, this is the only way the air can get under the edge -- the edge has to deform in order to lift up to allow the air to penetrate.

And this is the second problem with the situations I had with the tubes and why shooting air into it never seemed to work for me. The fiberglass portion of the matrix resists deformation. That is what makes fiberglass strong. It doesn't stretch like a plastic.

So when you try shooting air into it, you are in effect trying to get the glass fibers to stretch and allow the tube to deform to accept the air bubble of compressed air. What happens is that the individual fibers crack in order to allow the epoxy to stretch.

After the fibers crack, the tube zippers down the side when you try to force the air under the edge. I don't have a picture to show you of this, but trust me on this… It tears quite readily. These tubes are so thin that they just don't have any resistance to tearing at all.

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Newsletter Staff
Writer: Tim Van Milligan
Layout/Cover Artist: Chris Duran
Proofreader: Michelle Mason

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"Try Freezing it Tim"

Another suggestion that I've heard dozens of times when explaining the process of removing the tube from the mandrel is: "Why don't you freeze the mandrel to shrink it?"

I've tried this a bazillion times too. Have you tried handling the super cold metal mandrel to try to slide the fiberglass shell off? It is so cold, you can't hold it for longer than 30 seconds. So you have to use thick gloves to hold it. And now you can't grip it well, and it is the rougher handling which then tears the fragile part.

I should have looked this up earlier. But the reason why freezing doesn't work is due to the coefficient of thermal expansion of aluminum versus the epoxy/fiberglass matrix. Aluminum has a lower coefficient of thermal expansion than that of fiber reinforced epoxy (http://www.engineeringtoolbox.com/linear-expansion-coefficients-d_95.html). So when chilled, the epoxy/fiberglass matrix shrinks faster than the solid aluminum mandrel. In effect, it gets tighter on the mandrel the colder it gets.

Because of the miserable results I got when I tried freezing the mandrel and using compressed air to remove the fiberglass tubes I ended up concentrating on different types of mold releases.

Experimenting With Mold Releases

In the previous newsletters I talked about the first three on the left in the photo (**Figure 1**). The Crown #3470 aerosol wax was the old stand-by. It does work, but you have to heat the mandrel in order to melt the wax to get the tube to slide off. The heat can sometimes deform the fiberglass, and the wax build-up has to be cleaned off as a secondary operation.

Figure 1: The different types of products that I experimented with as mold releases.

The automotive carnauba wax is a paste that is applied and then buffed off the mandrel. It was a disaster. Avoid it as a mold release.

Next was the Challenge #95 from BJB Enterprises. It is a thick viscous liquid with wax embedded into it. You paint it on with a brush, and then buff most of the wax off before laying down the fiberglass and epoxy resin. It does work, but takes a lot of slow labor to work the tube off the mandrel. It was my new go-to release for a long time. But even then I still ruined a bunch of tubes, so I continued to search for a different release.

Blue Magic

My mandrels were pretty shiny. I polish them with ultra fine 0000 steel wool between lay-ups. I want them as smooth as possible, so that the epoxy has fewer scratches to seep into.

One product that I tried as a way to make them smoother as well as a mold

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release is a "metal polish." Until this experiment, I had never tried this stuff, and I was very impressed at how shiny the mandrel became.

It is a rubbery paste. Rubbery is how I describe it, because when you shake the can, you can feel it shaking around in response. It is just weird stuff. When you apply the blue colored goo and start spreading it around with rubber gloves, the stuff turns pitch black. That is how it works. Once it is black, you buff it off with paper towels. In a couple of minutes of effort, it is super shiny.

There are several brands, but they all do much of the same thing. They bring out the shine in the aluminum, almost to a mirror appearance.

I did some research on metal polishes and found it is mostly a chemical cleaning. Regardless of the brand you get, they work in three ways to bring out the shine:

1. Mechanical: It contains abrasives which remove the microscopic "peaks" (which show up as dullness) from metal.

2. Chemical: It contains solvents which "clean" the metal, removing oxidation, grime, and debris from the mechanical polishing process. Removing the oxidation is what really brings out the shine.

3. Sealant: Most also contain some sort of sealant (typically silicone-based) which "seals" the metal and protects it (for a short time) against future oxidation.

It was like a miracle when I saw it, especially how little effort it took to shine it up. So I suspected that it really wasn't as smooth as it looked. But the jar said it had a silicone agent in it, so I thought I'd try it out.

As an experiment, I took an old aluminum mandrel and split it in two with a strip of tape (see **Figure 2**). On one side I used the Challenge 95 release because it was my old reliable release, and on the other side, I tested the new product as a mold release. I did this for all the future experiments to speed things up.

Figure 2: Split testing of mold releases. A mandrel was divided in half by green tape so I could see which mold release worked better. The right side has Challenge 95 mold release on it, but not buffed off yet.

Unfortunately, the metal polish did not work very well. I didn't take any pictures of it at the time, but it just wouldn't lift up. I could only get it to dislodge from the mandrel by tearing it off.

Even though I don't use it as a mold release, I keep it around and shine up the mandrel every once in while. It just looks really cool when it has a mirror appearance.

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Silicone mold releases

Next I tried an aerosol silicone spray (Liquid Wrench brand) that I purchased from my local hardware store. This stuff was by far the worst stuff I tried, at least as bad as the automotive carnauba wax. **Figure 3** shows how it left the epoxy stuck to the mandrel when the fiberglass cloth was pulled off.

Figure 3: The epoxy stuck too well to the aluminum with the liquid wrench release.

I can tell you that I spent a couple of hours trying to get all the epoxy removed from the mandrel after this experiment. You have to carefully scrape off the surface with a knife blade - working slowly to avoid scratching the mandrel with the metal blade (steel is harder than aluminum, so it can be easily scratched). Then you have to remove the remainder of the epoxy with steel wool. You do this once, and I guarantee that you don't ever want to repeat it.

The Liquid Wrench has been retired to my garage, where I use it to spray my snow shovel in the winter.

At this point, I started calling around and getting recommendations. The engineers at BJB recommended two products that I might try. The first was Release #79. They thought that this might work well for my application, because they said that a company that made pole-vault poles used it to make their 18-foot long shafts. Based on this, I ordered up a can.

The Release #79 is pure liquid silicone. You simply paint it on with a brush or air gun, and apply the fiberglass/epoxy right over the top.

This stuff did work. I'd say it worked about as well as the Challenge #95. Maybe a little better, because with the Challenge #95 you had to worry about little spots on the mandrel that didn't get covered well with the thick paste-type liquid. The Release #79 was water-thin, and easily spread out when you covered the mandrel.

Pulling the tube off the mandrel was ok, but different in a way. It left liquid on the surface of the mandrel. So you have a bit of water-like surface tension between the fiberglass tube and the mandrel. It was just a different technique than was used to using compared to the Challenge #95 mold release.

The disadvantage of the Release #79 was that it had a very oily touch to it. In other words, it was hard to remove the oil from the finished fiberglass tube. If it is hard to glue fins to a tube with wax on the surface, it is twice as hard to get them to stick to oily silicone.

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Out of desperation, I tried the "Part All Hi-Temp Wax" mold release from Rexco. This is a paste-type wax, but it has Teflon® in it as well. It is put on like a car wax: you apply it with a cloth, let it dry, and then buff it off. But you don't let it fully dry; you want it just "mostly dry" so that it buffs off easier. If it is fully dry, it is very stiff and it is difficult to remove the build-up by buffing.

But as a mold release, it was by far the best of anything I tried! And I'd recommend it 100%.

The surface tension between the tube and the mandrel is easy to break by pushing the bubble around the tube. I made a video showing how I run my thumb around the tube to break the surface of the tube free from the mandrel. You'll find the short video at: https://www.youtube.com/watch?v=nCCRh226Avg

You can also break the surface tension by slightly twisting the tube. This takes a bit of practice to get the technique right, because if you twist too hard, you'll snap the tube right off. I've done that a number of times too.

Once you break the entire surface free from the mandrel, the tube can be slid off. But when you start, as you'll see in the previously mentioned video, you have to "pull" it from the small end. You have to pull until you break the vacuum that is created in the transition portion of the rocket. You'll see in the video that at one point I started pushing from the fat end and nearly crumpled the tube. Fortunately I caught it before the fiberglass cracked, and I continued pulling from the motor end.

One additional benefit of the Part-All Hi-Temp Wax is that it doesn't leave any residue on the inside or outside of the tube. The tube is ready to accept the glue for the fins and any rings you want to put inside.

The "Part All Hi-Temp Wax" works almost too good. I never thought I'd ever say "too good", but there is a point where a tube can come off too easily. I'll cover that in the next article.

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Fixing Surface Imperfections

After finding the right mold release agent to help remove the tube from the mandrel, I shifted my focus to another small issue. That was getting a high-quality surface finish on the rocket.

Looking at **Figure 4**, you'll see two problems that I had. The biggest one was the fiberglass cloth shifting positions and leaving a gaping hole in the side of the tube.

Figure 4: The two problems shown here are the fabric shifted when the it was inserted into the silicone rubber mold, and a dimple of epoxy on the surface of the tube (at the arrow point).

The cloth was shifting position during the process of sliding it into the silicone rubber mold. Essentially, the liquid epoxy was acting as a lubricant.

The solution was easy to fix. I had to let the epoxy start to cure a little bit and stiffen up before I shoved it into the silicone tube that served as the female mold.

The tricky part was how much time you had to wait for it to stiffen up. For reference, I was using the West Systems brand epoxy, which takes a full 24 hours to cure. I found that I had to wait an hour after putting the epoxy onto the fiberglass before it was ready to go into the mold.

But because it was stiff, it wouldn't go into the rubber mold easily. This led to a process of applying epoxy twice to the mold. The first batch was applied to the fiberglass that was on the mandrel and allowed to thicken. Just before it was slid into the mold, the mandrel was coated with a layer of fresh epoxy, which acts as a lubricant to allow it to slide into the mold easier.

Obviously, two layers of epoxy can be heavy. So the first layer has to be as thin as possible.

Initially, as shown in **Figure 15** and **Figure 16** in the previous newsletter (https://www.apogeerockets.com/education/downloads/Newsletter431.pdf), I'd wet out the cloth with epoxy on a sheet of glass and then transfer it to the mandrel. That way, only a little epoxy remained on the cloth.

This would then sit for one hour to stiffen up. At that point in time I'd put a second layer of fresh epoxy on the fiberglass and then shove it into the rubber mold. As it went into the mold, the excess epoxy is squeegeed off by the silicone as it slid into the mold. From here it would sit and cure fully overnight.

Therefore, the problem of the glass cloth shifting around was fixed by "process." I didn't change materials, just the order and time when they were applied.

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Getting Rid of the Epoxy Dimples

The other problem shown in **Figure 4 (Page 7)** is the little dimples of epoxy on the surface of the tube. In the last newsletter, I mentioned that I could simply sand them off. But that adds a secondary operation, and it scuffs up an otherwise shiny tube.

The dimples were occurring because of air bubbles that were trapped in the silicone rubber molds that I was using. Normally, I'd degas the silicone by putting the entire mold in a vacuum chamber. But these were really big molds, and my vacuum chamber couldn't hold them.

Here's why the dimples were forming. What was happening was when the PVC tube containing the silicone mold and the mandrel was being pressurized, excess epoxy, instead of sliding out from under the silicone mold (or evenly flattening out under the surface of the silicone rubber), was depressing the air bubbles in the silicone and staying on the surface (**Figure 5**). Once it hardened, it would leave a dimple of epoxy.

The solution was to change the type of silicone I used to make the rubber molds. Instead of using a soft silicone rubber (it had a blue color), I switched to a harder rubber. In engineering terms, the rubber went from a shore hardness of 25 to 40. Because it was harder, the epoxy could not easily push into the voids under the surface of the rubber.

The result was instantaneous. I got perfectly smooth tubes every single time! There was no additional secondary process (like sanding away blemishes) needed to make smooth tubes. They just came out nearly flawless, and only needed to have the ends trimmed to be a usable tube.

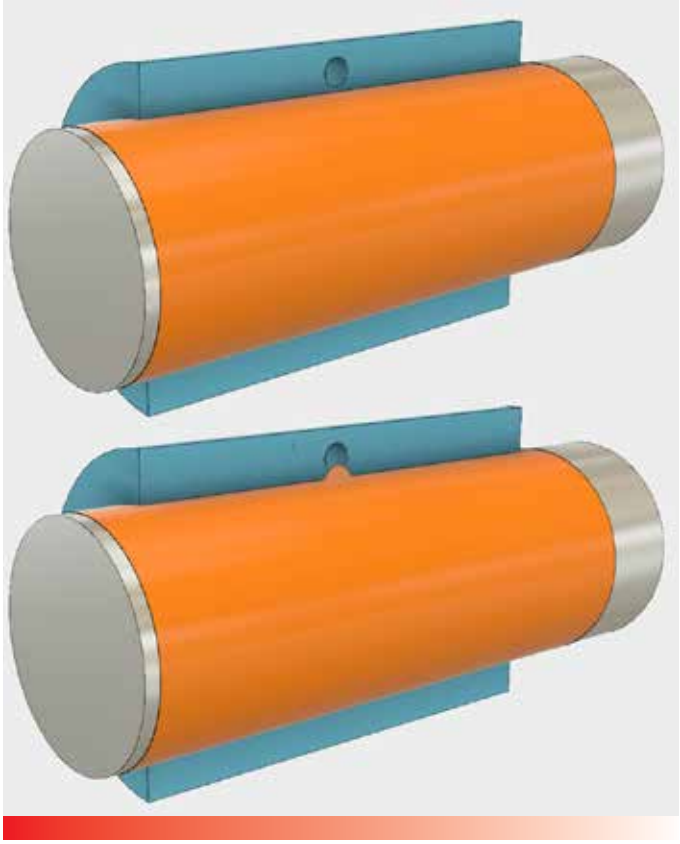

Figure 5: Cut-away view of the silicone (blue part). When an air bubble (called a void) is trapped in the silicone near the inside surface, the epoxy can deform the silicone and squeeze into the void, leaving a dimple on the surface of the part.

The only difference I noticed was how physically hard it was to remove the silicone from the aluminum mandrel (the very first time when making the mold). It was a

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really difficult time, because the rubber is so stiff and hard. I did have to use compressed air and a huge amount of effort to get the mandrel out of the silicone without cutting it apart. In hindsight, I'd make the wall thickness of the silicone rubber mold a lot thinner, just to be able to remove it more easily from the mandrel.

The good news is that once you are making a real part with fiberglass over the mandrel, it comes out really easy.

Next time

In the final installment in this series, I'll describe some of the other little tips and tricks that I developed, and then list the final step-by-step sequence that I now use to make fiberglass tubes.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor, and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward a M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and also the author of the books: "Model Rocket Design and Construction," "69 Simple Science Fair Projects with Model Rockets: Aeronautics" and publisher of the "Peak-of-Flight" newsletter, a FREE e-zine newsletter about model rockets. You can email him by using the contact form at: https://www.apogeerockets.com/Contact